

The background of the slide features a view of the Earth's horizon from space, with a bright light source (likely the Sun) positioned directly behind the horizon, creating a lens flare effect with numerous radiating lines. The letters 'E', 'L', and 'F' are spaced out across the top of the image.

E

L

F

# ENCELADUS LIFE FINDER

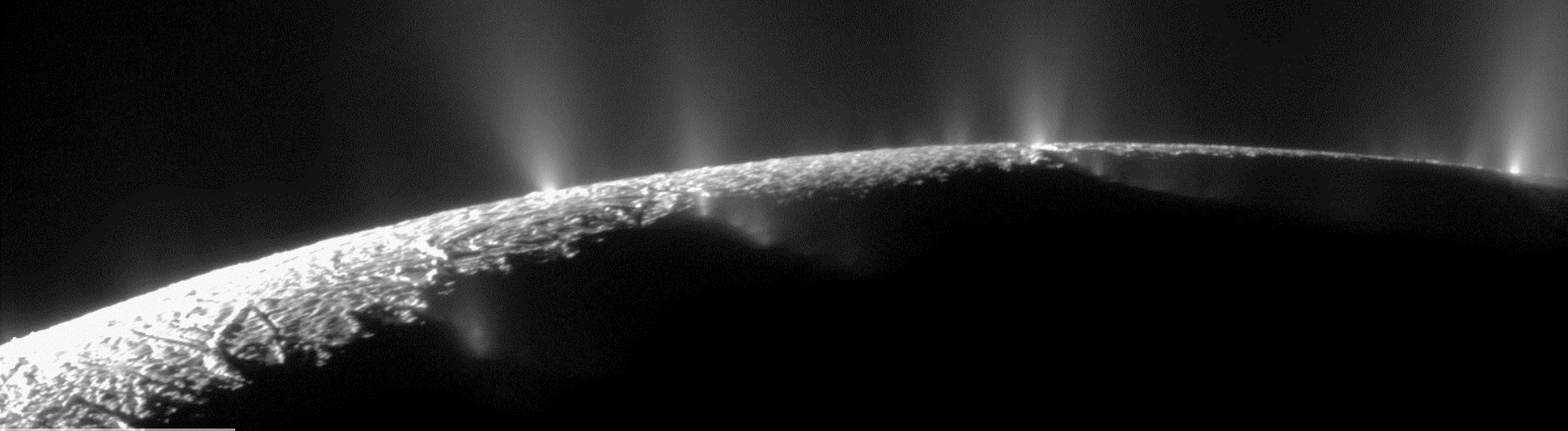
Morgan L. Cable, Jonathan I. Lunine, Linda J. Spilker and the ELF Science Team

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NASA Jet Propulsion Laboratory, California Institute of Technology

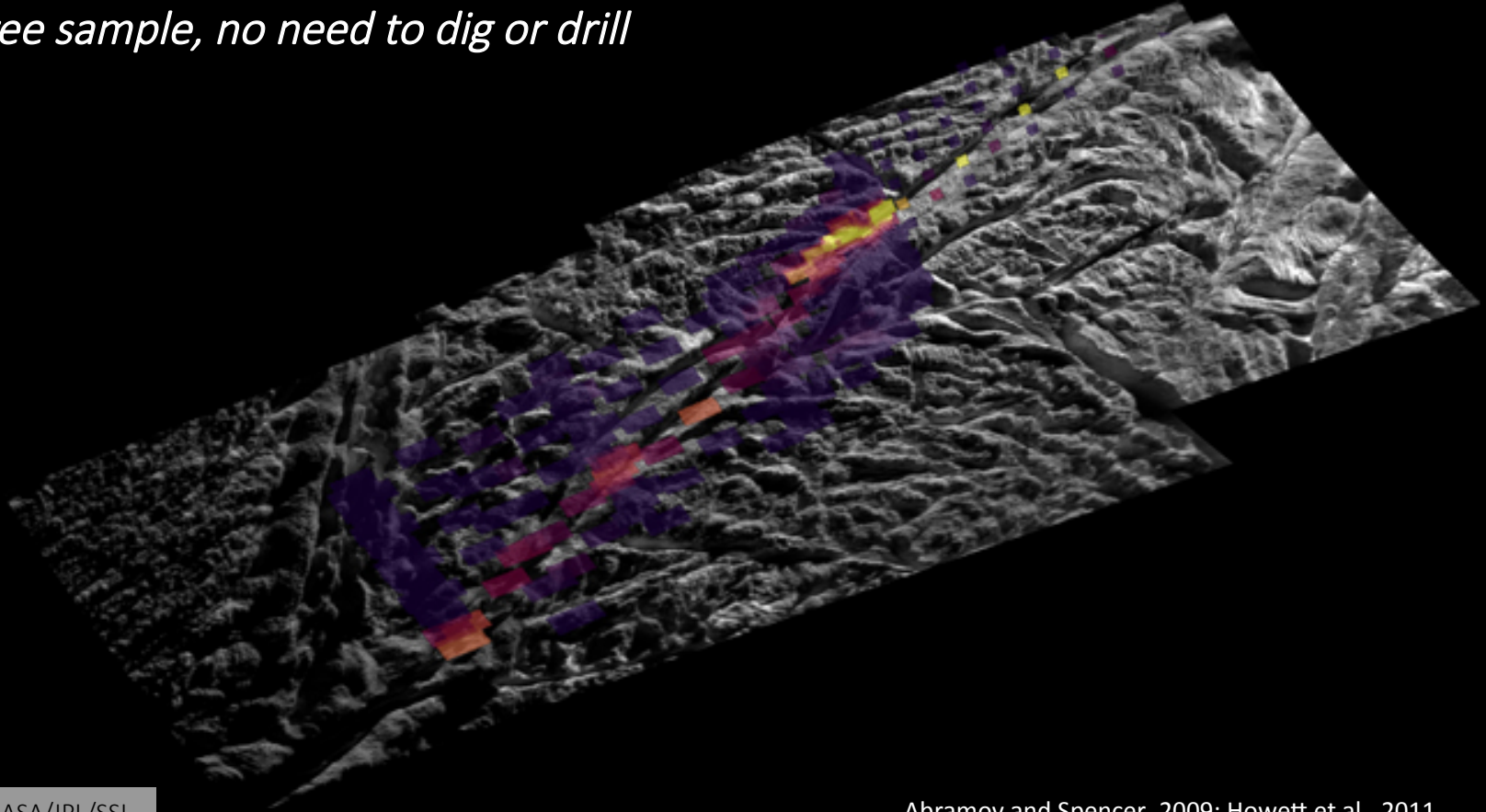
# Enceladus: Active, Astrobiologically Relevant, Accessible

*Free sample, no need to dig or drill*



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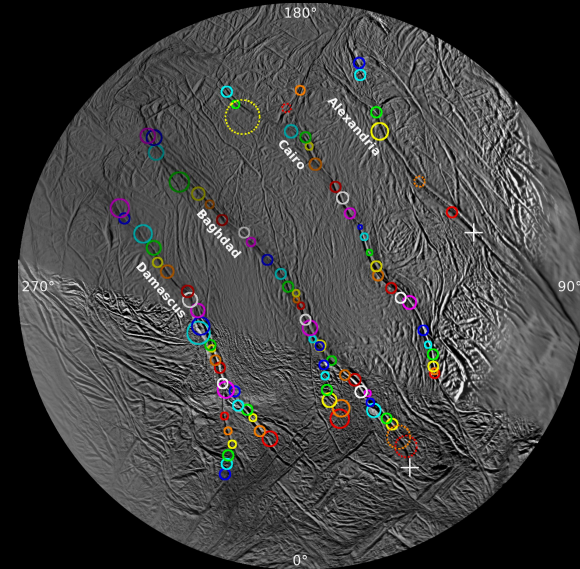




# Enceladus: Active, Astrobiologically Relevant, Accessible

*Free sample, no need to dig or drill*

- ~100 distinct, collimated jets emanating from Tiger Stripes that form a single plume
  - Modulated by diurnal tidal flexing

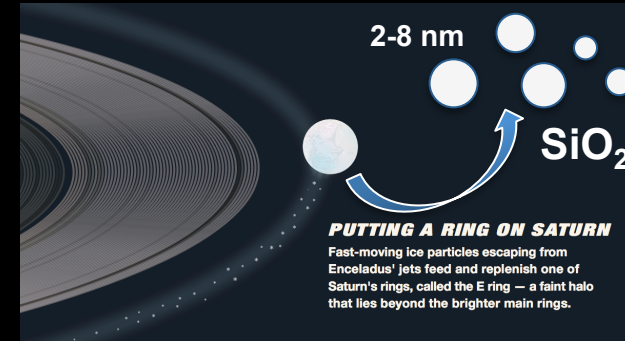




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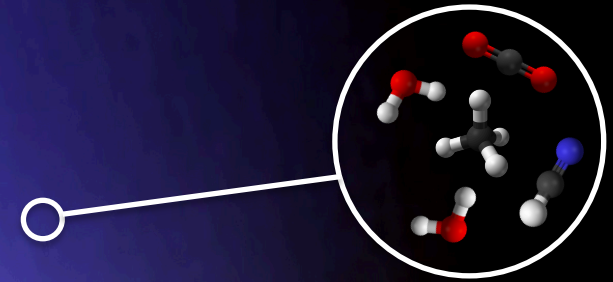
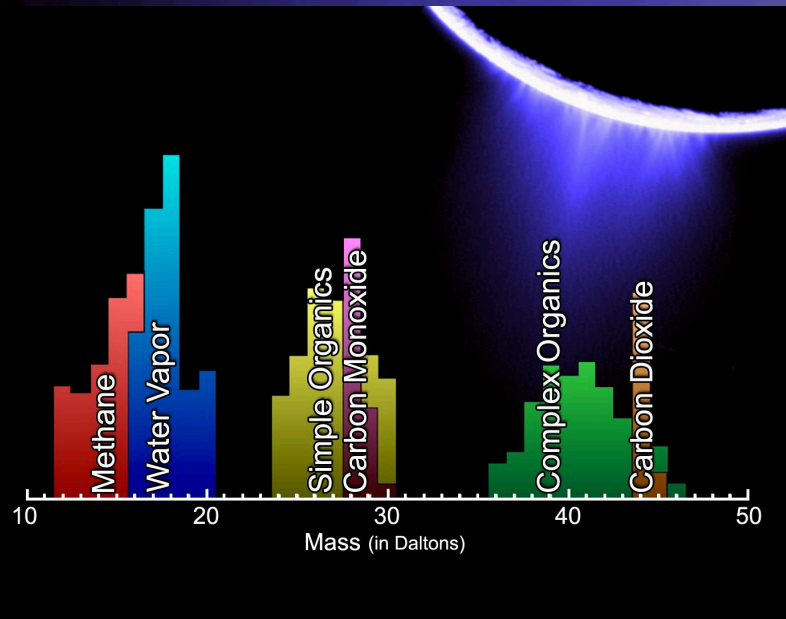
*Free sample, no need to dig or drill*

- ~100 distinct, collimated jets emanating from Tiger Stripes that form a single plume
  - Modulated by diurnal tidal flexing
- Plume feeds the E ring
  - Decay time constant of at least 100 years
  - Silica nanograins suggest recent hydrothermal activity



# Plume Composition

*Organic-rich, sourced from the subsurface ocean*



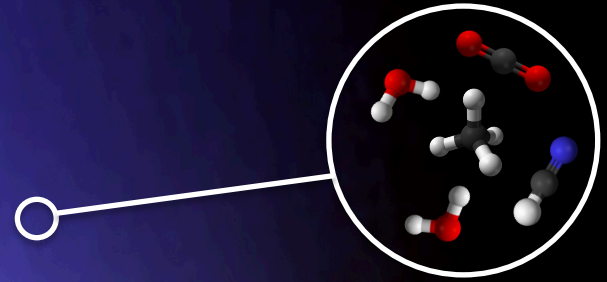
## Plume gas

- $\text{H}_2\text{O}$ ,  $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{NH}_3$ ,  $\text{H}_2$  (yay!), heavier hydrocarbons, **simple and complex organics**
- Mass flux: 200 kg/s

Constituent	Mixing ratio (%)
$\text{H}_2\text{O}$	96 to 99
$\text{CO}_2$	0.3 to 0.8
$\text{CH}_4$	0.1 to 0.3
$\text{NH}_3$	0.4 to 1.3
$\text{H}_2$	0.4 to 1.4

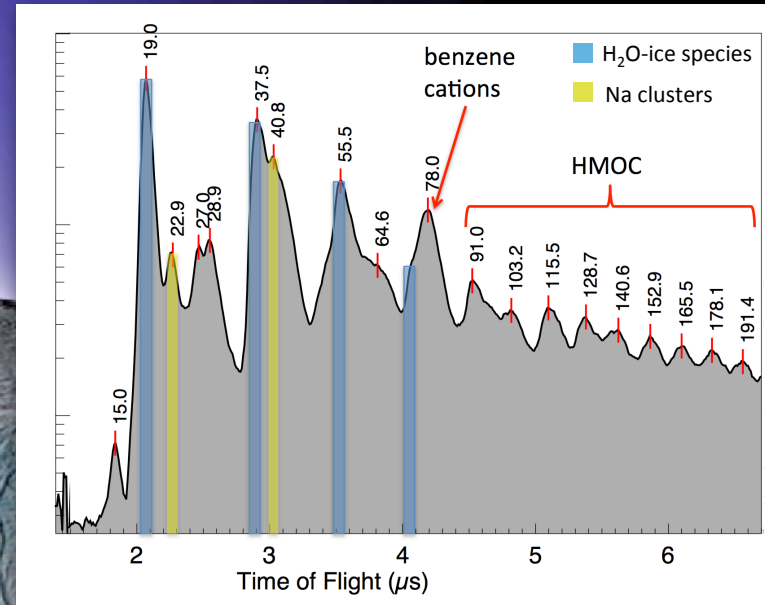
# Plume Composition

*Organic-rich, sourced from the subsurface ocean*



## Plume grains

- Water-ice, salts (mostly NaCl), SiO<sub>2</sub>, **high mass organic cations (HMOC)**
- Mass flux: 50 kg/s (~10% of particles reach escape velocity)

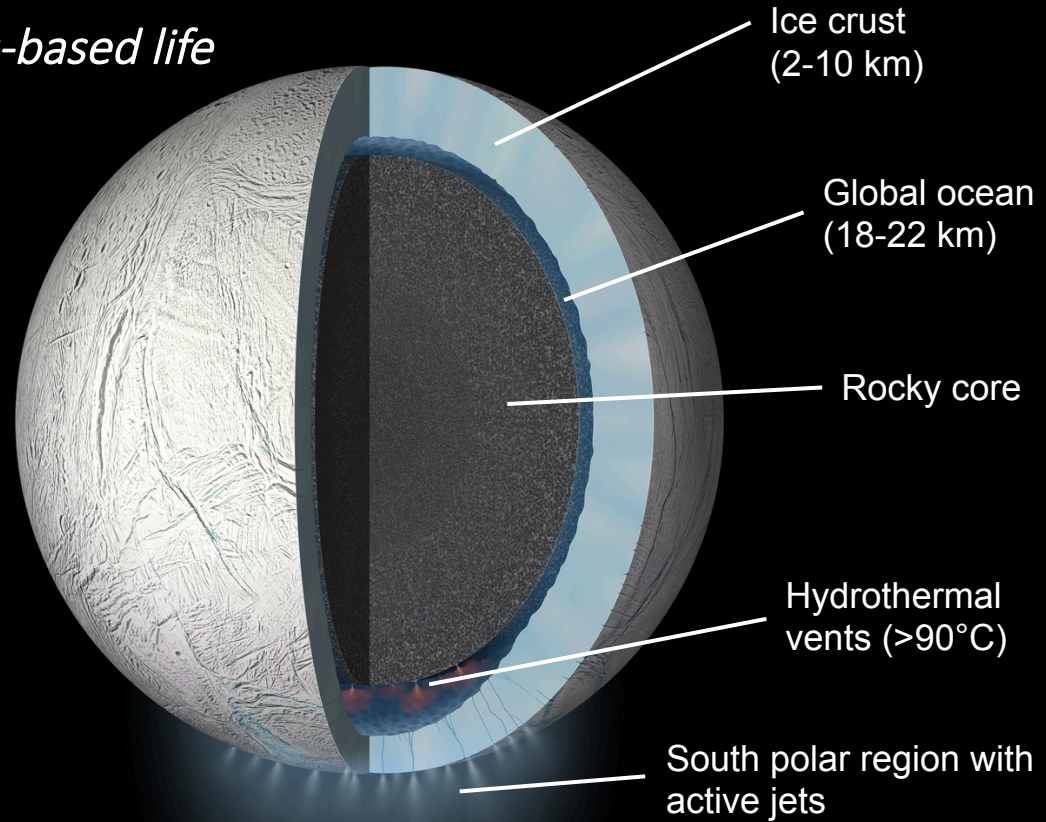




# Enceladus Awaits

*An ideal place to search for aqueous-based life*

**WE NEED TO GO BACK**



# Lessons from Cassini

*When 'in situ', do as the mass spectrometers do*

- In situ detection of biomarkers is key
  - Remote sensing can support these measurements, but is no substitute
  - Cassini Ion and Neutral Mass Spectrometer (INMS) and Cosmic Dust Analyzer (CDA) demonstrated the power of mass spectrometry for in situ plume science
- Limited sample size makes sample processing difficult
  - Density of gas and grains in the plume is low ( $\sim 5 \times 10^{-5}$  g collected on a  $1 \text{ cm}^2$  area for a 50 km flythrough)
  - Simplicity over complexity (no GC or LC)

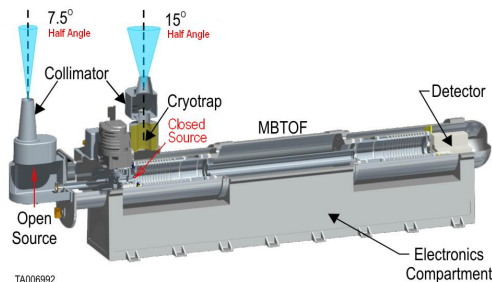
# ELF as the Next Logical Step

*A robust instrument suite that targets plume gas and grains to search for life*

## MASPEX

Mass Spectrometer for Planetary Exploration

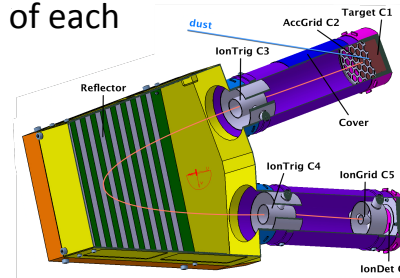
- Target: Plume **gas**
- Extended mass range for heavy organic molecules
- Enhanced mass resolution for critical isotopes
- Enhanced dynamic range for high S/N
- Improved sensitivity (better than 1 ppt with cryotrap) for rare noble gases



## ENIJA

Enceladus Icy Jet Analyzer

- Target: Plume **grains**
- Heritage: Giotto, Stardust CIDA but improved ion optics, ion detector, spectra processing
- Segmented target for low and high-rate spectra mode (compositional profile with 100 m spatial resolution)
- Complete composition of each ice grain, over a wide mass range

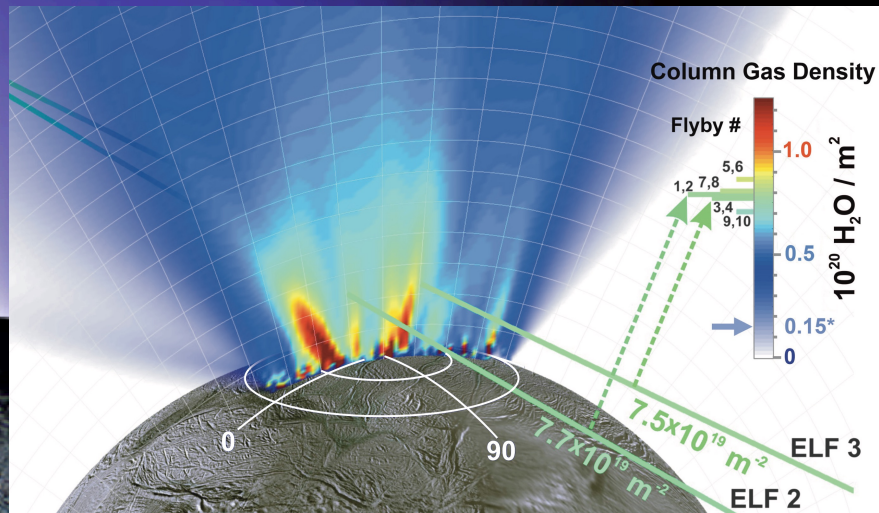




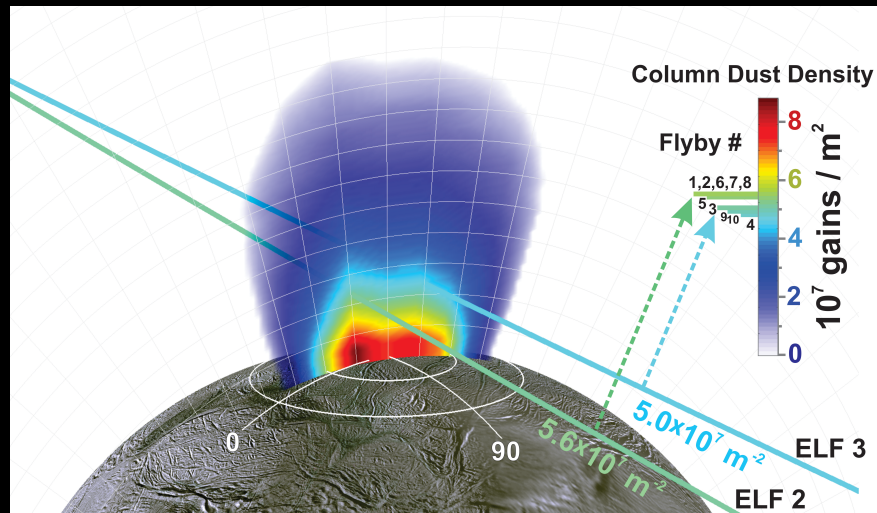
# Plume Modeling

*Know before you go*

Plume Gas Model

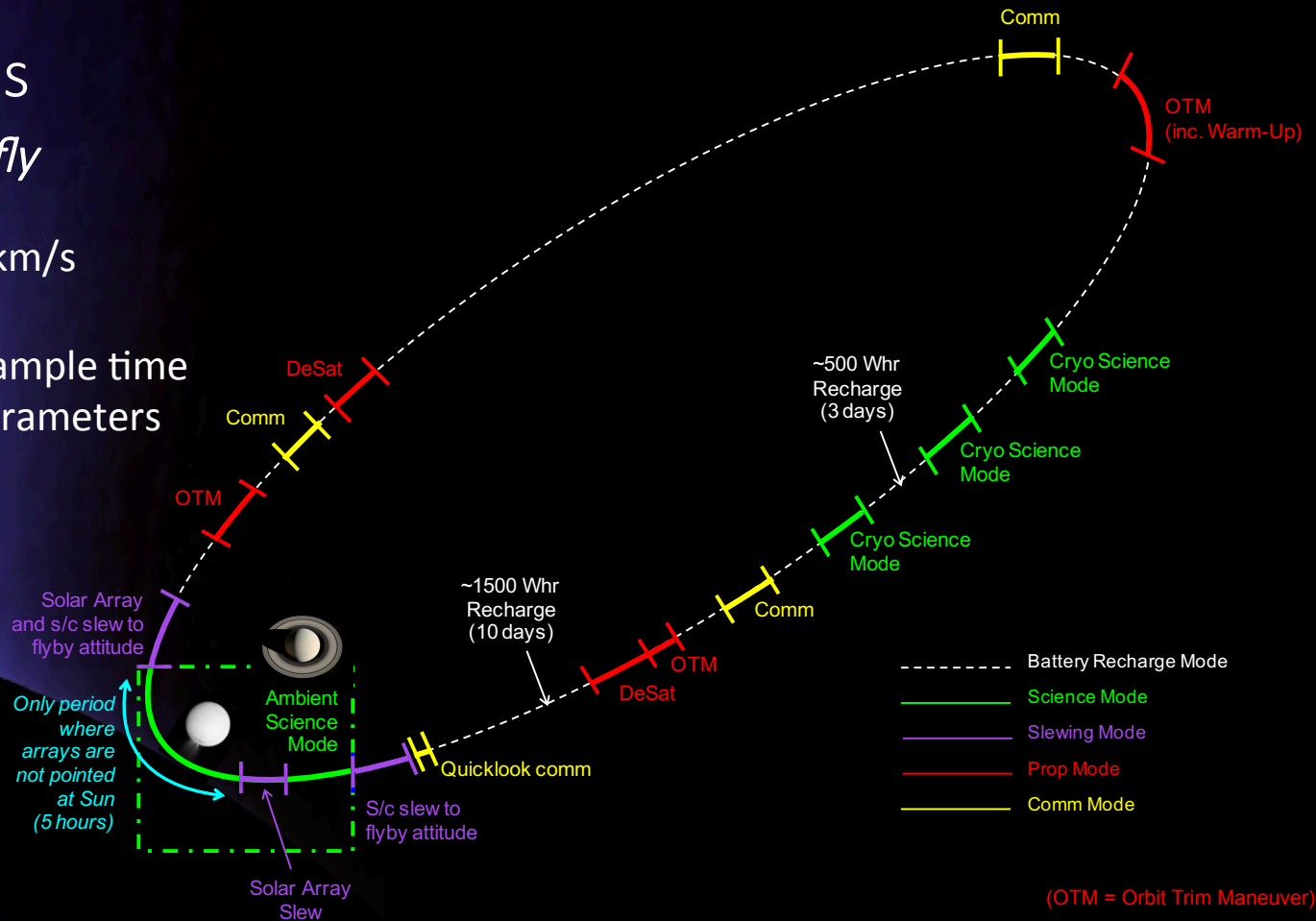


Plume Grain Model



## Life detection on the fly

- 10 flybys, each at 5 km/s
- 62-day orbit allows ample time to set instrument parameters for the next flyby



# ELF Science Investigation

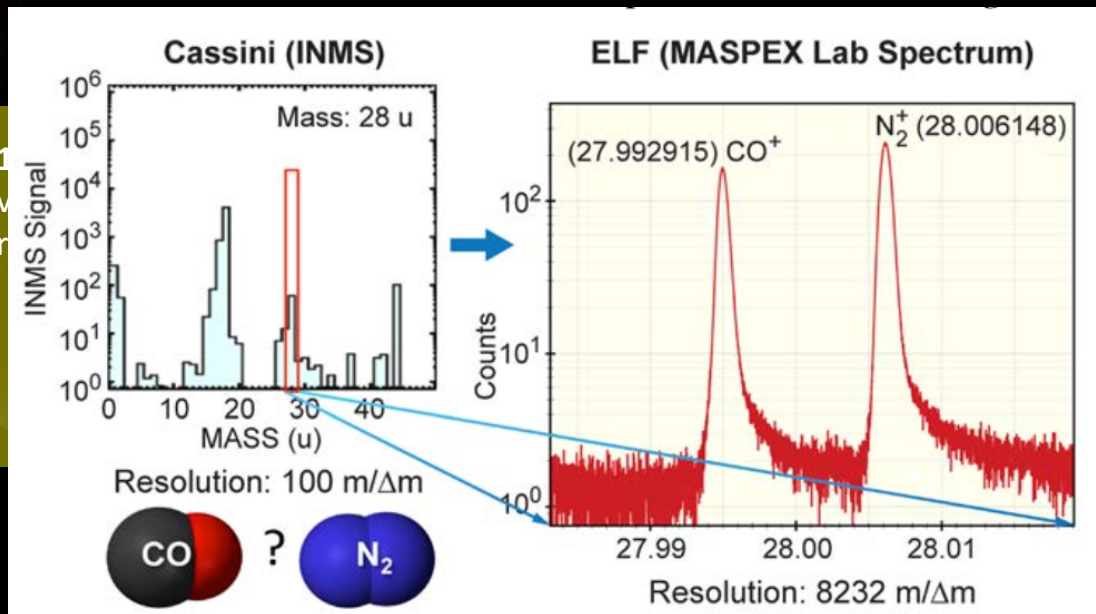
*Three objectives, one profound question: Is there life beyond Earth?*

## Science Objective 1: Evolution

Determine if Enceladus' volatiles, including organics, have evolved over time.

### Nitrogen as an Indicator

**1a.** Determine the original molecular carrier for nitrogen as an indicator of the degree of volatile evolution on Enceladus.





# ELF Science Investigation

*Three objectives, one profound question: Is there life beyond Earth?*

## Science Objective 2: Habitability

Determine if the ocean of Enceladus satisfies the basic requirements of habitability.

### Temperature

**2a.** Determine the temperature of the ocean and possible hydrothermal systems to within 100 K.

### Redox Energy

**2b.** Quantify the amount of redox energy available.

### Oxidation State

**2c.** Determine the oxidation state of the ocean.

### pH

**2d.** Determine the pH of the ocean to within an accuracy of 1 unit.

# ELF Science Investigation

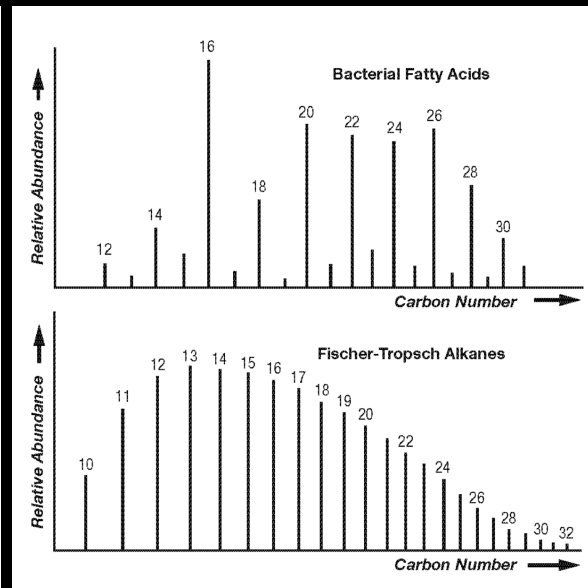
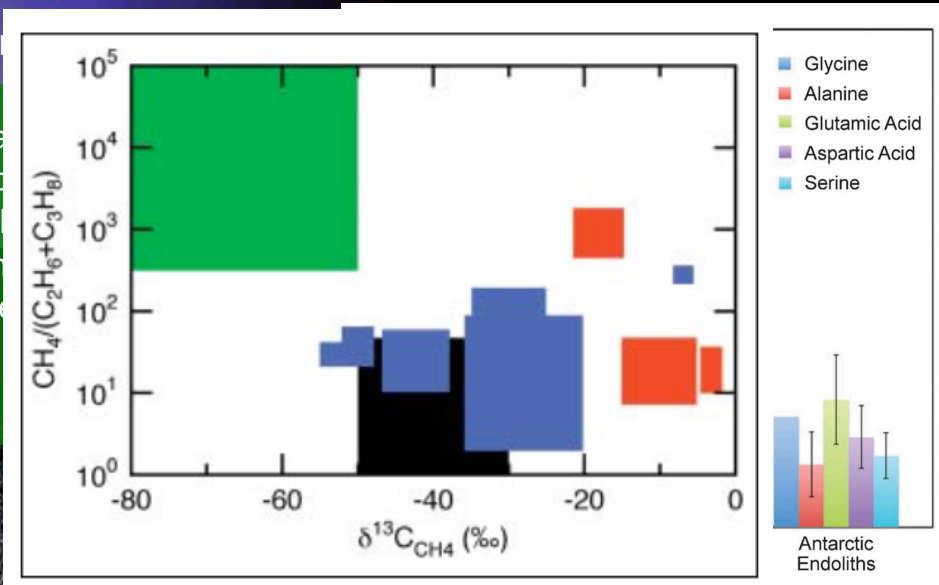
*Three objectives, one profound question: Is there life beyond Earth?*

## Science Objective 3: Life

Determine if the plume of Enceladus contains chemical signatures of biology.

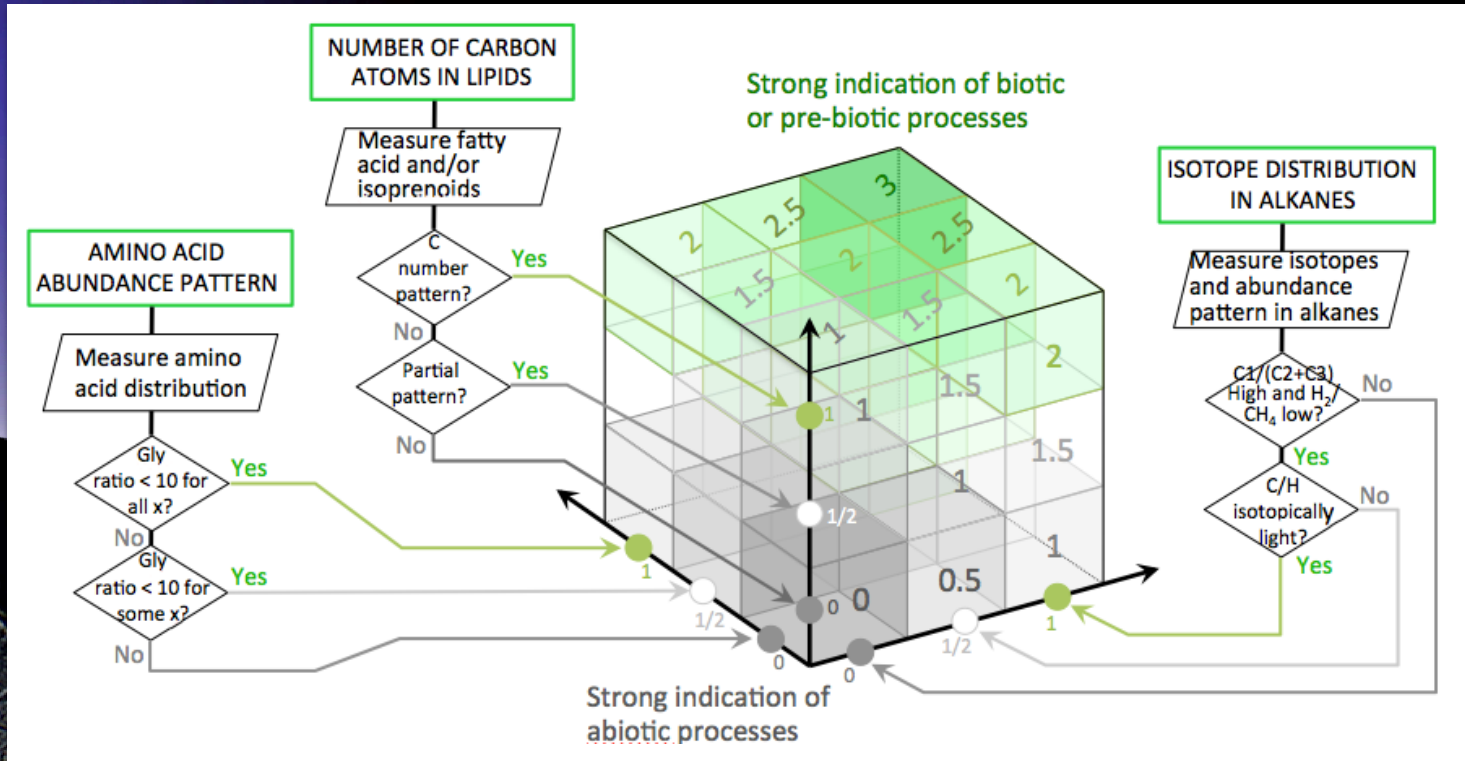
Amino

**3a.** Look for patterns in amino acid distribution that are consistent with biological synthesis, underrepresented relative to other forms, or that are energetically favorable.



# A Life Investigation Within Reach

*Multiple, independent tests for life shrink the ambiguity box*





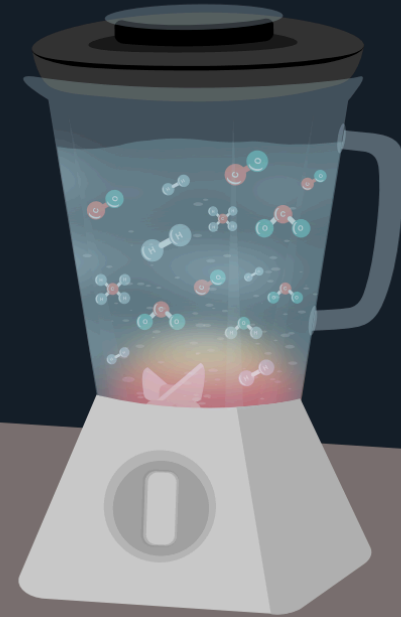
# Enceladus Awaits

*An ideal place to search for aqueous-based life*

- There is definitive evidence of a subsurface ocean with organics, salts, and free energy.
- The plume of Enceladus includes ocean material and is readily analyzed for evidence of life—a goal of the **Enceladus Life Finder**.

## **INGREDIENTS FOR LIFE**

With its global ocean, unique chemistry and internal heat, Enceladus has become a promising lead in our search for worlds where life could exist.



# Acknowledgements

*So long, and thanks for all the fish*



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